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UCRL-PROC-206316

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August 31, 2004

Second International Conference on Multiscale Modeling
Los Angeles, CA, United States
October 11, 2004 through October 15, 2004

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ABSTRACT

A 3-D image correlation system has been used to study the deformation behavior of high purity molybdenum single crystals. This system, in conjunction with a recently developed experimental apparatus, provides the full field displacement and strain data needed to validate dislocation dynamics simulations. The accuracy of the image correlation system was verified by comparing the results with data taken from conventional strain gage rosettes. In addition, a stress analysis has been performed to examine the non-uniformities in stress. The results of the analysis show that after the sample has been strain 2%, the axial stress in the sample varies by ± 20%.

1. Introduction

With the continuing development of a massively parallel dislocation dynamics simulation to achieve appreciable strains [1], there is a continuing need to develop experiments to validate these simulations. Recently, a “6 Degrees of Freedom” (6 DOF) experiment was developed to validate dislocation dynamics simulations of plastic flow of bcc single crystals up to strains of approximately 1% [2]. This unique experiment essentially imposes a compressive uniaxial stress state on the sample, while allowing the crystal to deform in 3 orthogonal translation directions and 3 rotation/tilt axes. At larger strains (> 2%), the anisotropic nature of slip in single crystals may cause severe shape changes to develop. Traditional strain gages, while accurate, only measure strain at one point, and are limited by the amount of strain they can measure (< 1.5%). Shape changes may also lead to non-uniformities in the applied stress state, making it difficult to directly compare with simulations. Therefore, a full 3-D strain measurement in conjunction with finite element analysis is needed. A commercial 3-D non-contact image correlation system, from Trilion Quality Systems, was used to measure the full-field strains during a 6 DOF experiment on high-purity single crystal molybdenum samples.

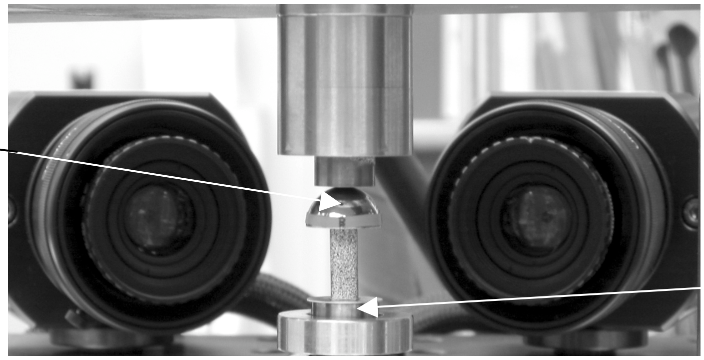

Figure 1-Picture of the large strain testing set-up.

In the 3-D image correlation method, a random speckled pattern is applied to the surface of the sample before deformation. A CCD (charged couple device) camera takes a picture of the sample before and after a given strain amount. The two photos are compared using commercial image correlation software, and the displacements of the spots are measured [3]. Knowledge of the displacements allow for the calculation of the strains. By using 2 cameras/face, the complete 3-D displacement field can be measured and the rigid body motion can be eliminated. A picture of the testing set-up is shown in Fig. 1. The compressive load is applied to a half sphere, which allows the sample to tilt, while the translation platen allows for full range of motion in the x-y plane. Unlike traditional testing techniques, this unique set-up allows essentially unconstrained deformation of the crystal.

2. Results and Discussion

As shown in Fig. 2, an axial strain map can be superimposed onto a picture of the sample. For this example, the global axial strain was 2% and the results show that while most of the sample has uniform strain, there are areas that show differences in strain. For instance, the triangular area of maximum strain that occurs in the middle of the sample corresponds to an area bounded by the crystallographic planes where the maximum slip activity is calculated to have occurred [2]. Fig. 2 also shows the corresponding stress and strain data in comparison with strain gage data. The axial strains for the image correlation experiment are calculated by averaging the strains over an area similar to the active region of a strain gage. The close match between the two experiments verifies the accuracy of the image correlation technique.

Since the sample can distort during the deformation experiment, a detailed FEM analysis has been performed on a deformed sample to examine the non-uniformities in the stress state. Using the FEM package NIKE3D, a mesh was created from the dimensions of the deformed sample and then an elastic load was applied. This analysis gives an approximation of the stress state without having to assume any plasticity laws. The

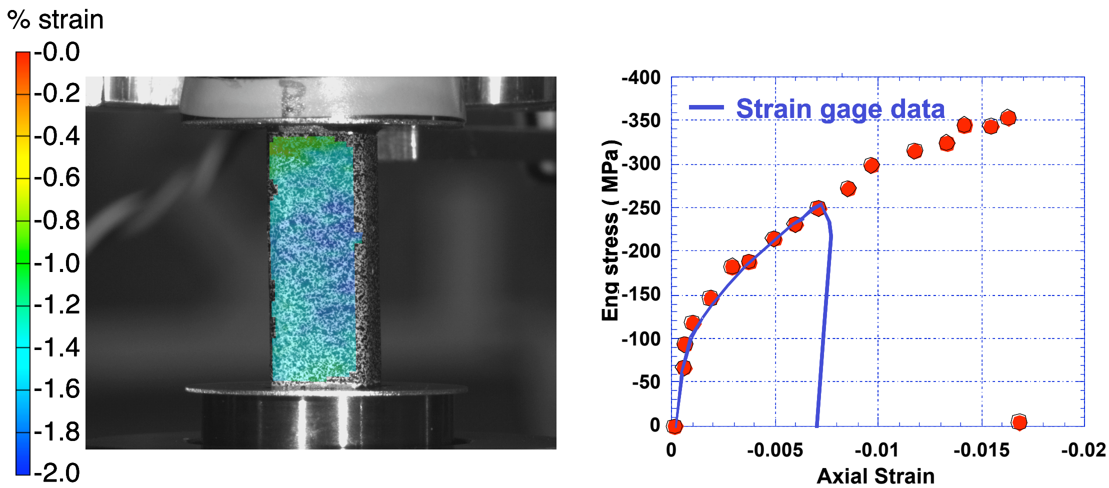

Figure 2- Axial strain results using the image correlation system. The corresponding stress strain curve is shown on the right.

results of the analysis show that at 2% strain the uniaxial stress in a horizontal cut though the center of the sample varies by ± 20%.

3. Conclusions

A commercial image correlation system has been used to examine the deformation response of a molybdenum single crystal to 2% strain. The results show good agreement with previous experiments conducted with strain gages. The image correlation method is also able to examine the full field strains, and areas of high strain correspond to planes of maximum deformation. A stress analysis has also been performed and shows that the due to the distortion of the crystal, the axial stress in the sample varies by ± 20%.

4. Acknowledgments

This work was performed under the auspices of the U.S. Department of Energy by the University of California, Lawrence Livermore National Laboratory under Contract W-7405-Eng-48.

5. References

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